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ONR Grant Award No. N00014-14-1-0010

Adaptive Meshing of Ship Air-Wake Flowfields

Progress Report

March 3, 2014

The objective of the proposed research is to deliver enhanced mesh adaptation capabilities that account for the chaotic unsteady nature of the flowfield in the landing approach path. The research will explore three distinct meshing methods to handle the dynamic aspect of this case. The three methods include a hierarchical Cartesian hexahedral method, an all-tetrahedral mesh method and a physics-based point placement meshless method. The initial phase of the research will develop pseudo-steady analysis procedures for each method, with appropriate mesh adaptation capabilities. The goal of the research is to compare and contrast the adaptive meshing technologies of the three approaches.

Common configurations, including carrier and aircraft, will be simulated with each method. Where feasible common software components will be used by all three methods. These will include geometry libraries, spacing field libraries, flux functions, time integration routines and others. Three distinct computer codes are being developed in the process and will link with these common components. The creation of the three computer codes has begun. Initial results for two of the methods are provided in this report; the hierarchical Cartesian mesher/solver and the all-tetrahedral solver.

The Cartesian code, named OctFlow, has capabilities similar to the SPLITFLOW code developed by Lockheed Martin.[1] OctFlow utilizes an Octree data structure and performs cut-cell operations at geometry boundaries. A second-order spatial finite-volume scheme has been incorporated with explicit first order backward time integration. The Cartesian mesh is generated automatically based on the input geometry, which is supplied as a triangulated surface mesh. The cells intersected by the geometry are handled using the "cut-cell" approach, which is basically creating arbitrary polyhedral elements with appropriate surface boundary conditions. Any cells completely outside the computational domain are tagged external and not solved in the flow solution. This preliminary capability does not yet include solution-based adaptation.

The all-tetrahedral code, named TetFlow, reads an externally generated mesh comprised of tetrahedral volume elements and triangular surface elements. Meshes for this code are currently generated using Pointwise.[2] This code also uses a second order spatial finite-volume scheme with first order explicit time integration. Once the basic flow solution capability is developed the insertion of additional bodies (i.e. aircraft) will be incorporated into the code using the mesh rupture technique in three dimensions.[3]

Both codes use the same flux function to compute the inviscid flux on the control volume boundaries. The current formulation is the compressible inviscid Euler equations in conservation form. The codes are being modified to use a low-speed, preconditioning scheme to handle the mix of flow regions anticipated during the research.[4]

A notional aircraft carrier has been simulated with the two codes and is shown below. The surface mesh from the 3D mesh generated by Pointwise serves as the geometry for the OctFlow code. A crinkle cut view of the meshes from the two codes is shown in Figure 1. The cell-cutting process in OctFlow uses the triangulated surface mesh to cut into the volume elements. As a result a finer surface tessellation is generated, as can be seen in the left side of the image. The sizes of the Cartesian volume elements are dictated by the size of the surface triangles, so the local element sizes are comparable between the meshes. A top view of the surface meshes from each code is shown in Figure 2. A magnified view of the two meshes, shown in Figure 3, reveals just how different the two meshes are given the same boundary tessellation.

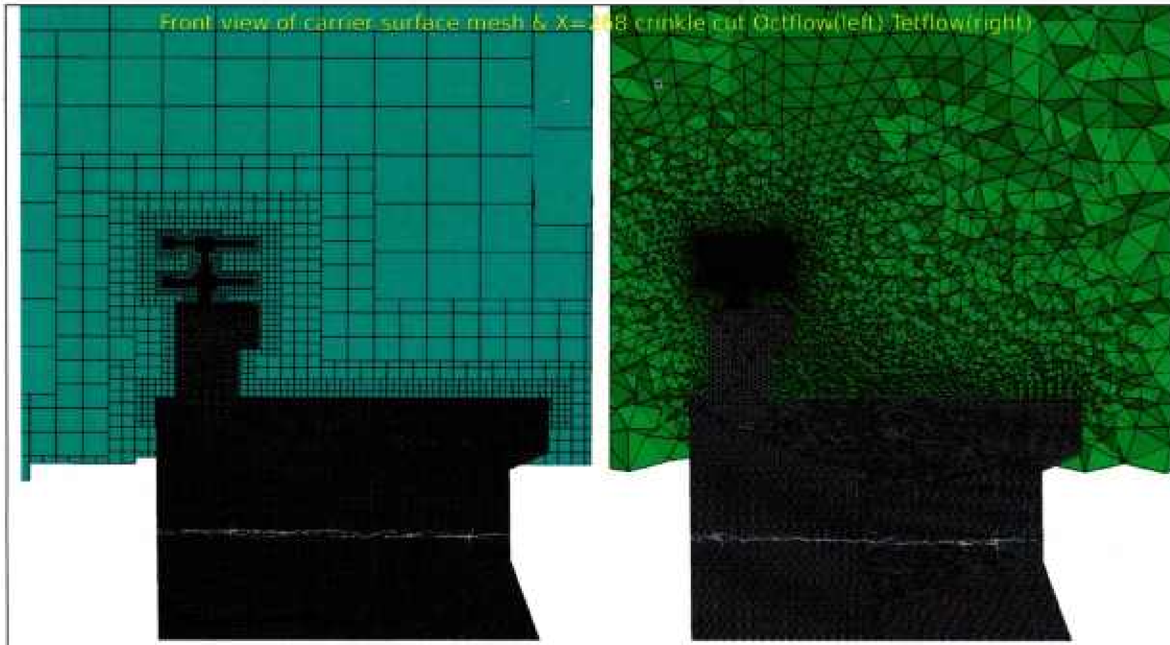

Figure 1. Side by side view of OctFlow and TetFlow meshes.

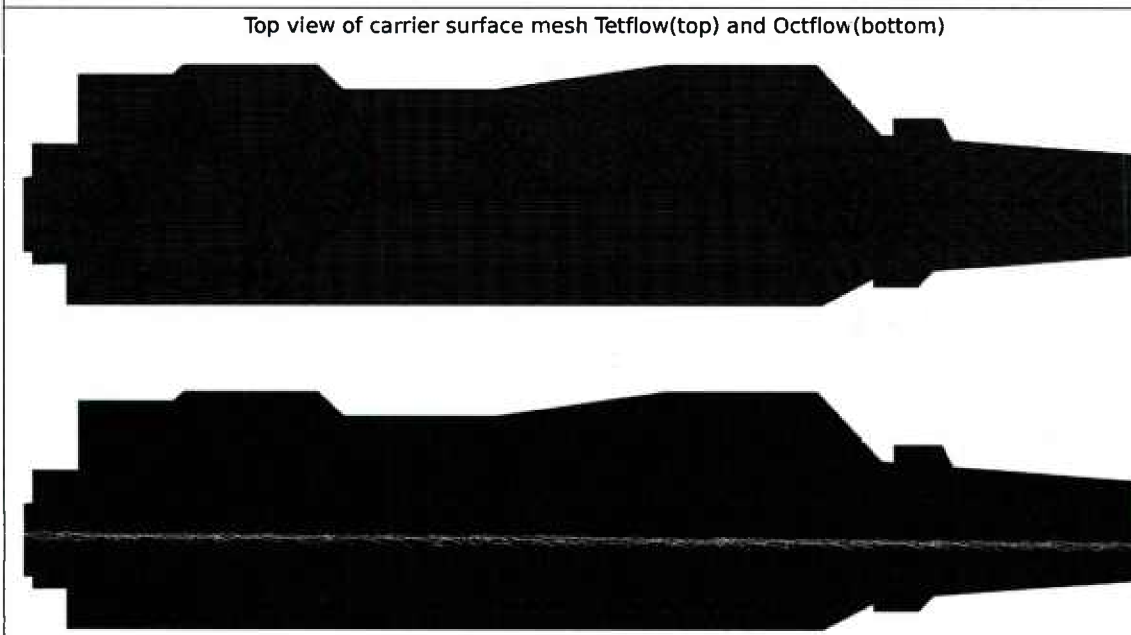

Figure 2. Top view of surface meshes from TetFlow and OctFlow.

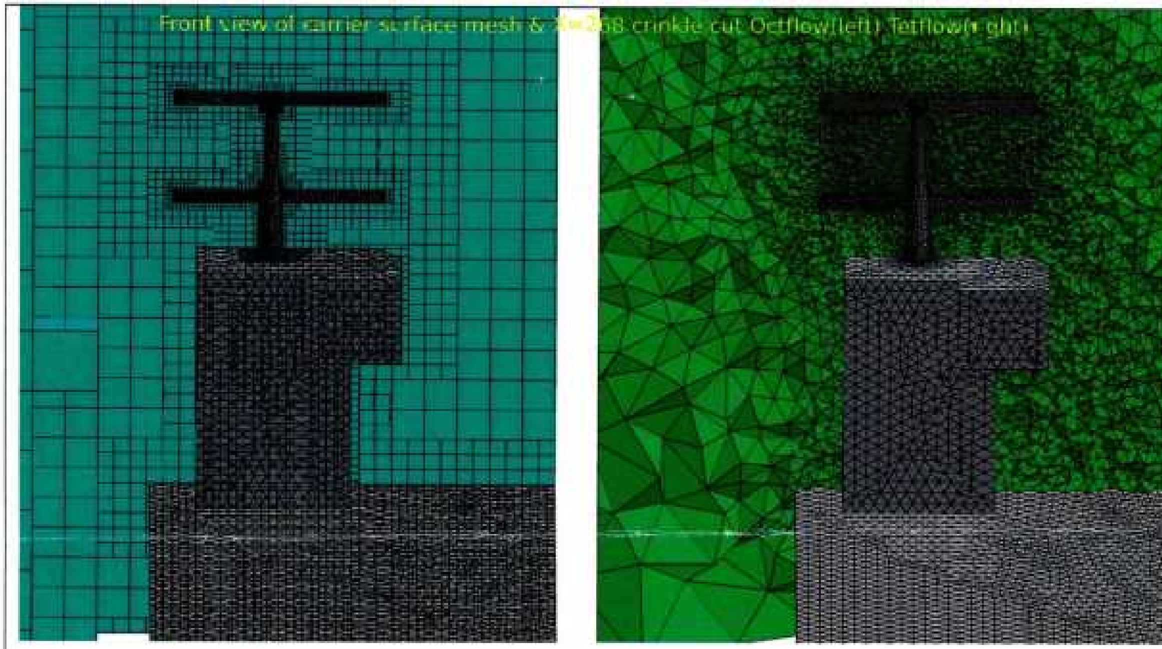

Figure 3. Magnified view of crinkle cut and surface meshes for two codes.

Some preliminary solutions have been computed on the two meshes. The flow conditions are Mach 0.1 inviscid flow directed head-on to the carrier. Figure 4 shows a side-by-side comparison of pressure contours on the carrier surface. The contour levels are set to match exactly between the two meshes. The element counts are quite different between the two meshes. The TetFlow mesh contains 515,939 nodes and 2,904,133 elements. The OctFlow mesh contains 1,313,044 nodes and 342,761 elements. One factor contributing to the larger node count in the OctFlow mesh is the surface cutting process. And tetrahedral meshes always have larger element to node ratios compared to other element types, especially hexahedral elements.

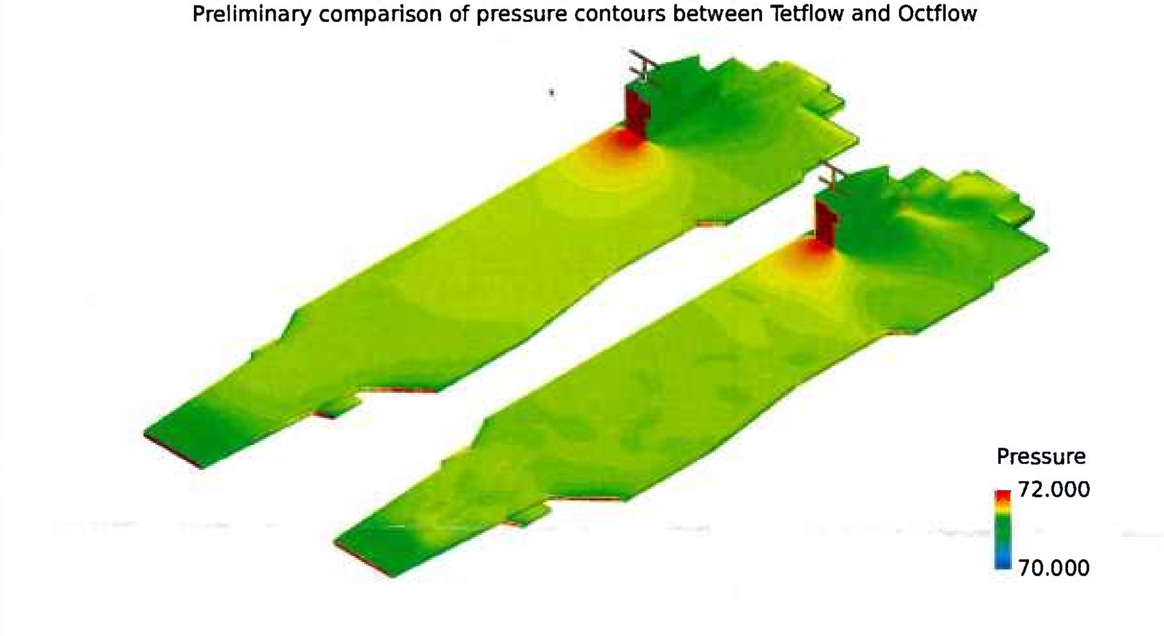

Figure 4. Pressure contours from preliminary TetFlow and OctFlow solutions.

The solution runs times are dramatically different. These initial results do not include any adaptive refinement in the OctFlow mesh, which would increase the element counts. The TetFlow mesh size should remain constant as the strategy involves inserting bodies into this mesh via the rupture technique. Adaptation of the TetFlow mesh will be through point movement, not refinement.

A next step in the research is to complete the modifications to low-speed preconditioning flux scheme and incorporate in both OctFlow and TetFlow. The third code, named PointFlow, is also in development. It is obviously more complicated than the other two. Previous work in 3D needs to be combined with knowledge gained in 2D by graduate student Philip Fackler in a code framework consistent with OctFlow and TetFlow. Some components will be directly shared, such as geometry and spacing libraries. Others will be dramatically different, such as post-processing visualization files.

References

1. Karman, S. L., Domel, N. D., "SPLITFLOW: Progress in 3D CFD with Cartesian Omni-Tree Grids for Complex Geometries", AIAA-2000-1006, 2000.
2. "Pointwise." Pointwise, Inc., http://www.pointwise.com.
3. O'Connell, M., and Karman, S., "Mesh Rupturing: A Technique for Geometry Insertion and Significant Mesh Movement", AIAA-2013-0148, 51st Aerospace Sciences Meeting Including the New Horizons Forum and Aerospace Exposition, Grapevine, TX, 2013.
4. Reed, C. L., Karman S. L., "Implementation of Low Speed Preconditioning in the Splitflow Code", AIAA-1997-1867, 1997.